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Influence of Temperature on the Structure and Properties of an Anodized Native GaAs Oxide

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Influence of temperature on the structure and properties of an anodized native GaAs oxide has been investigated by spectrophotometry, He back-scattering technique, He induced X-rays and mass-spectrometry and applications of the oxide for elevated temperature processing has been evaluated.

Previous investigations of anodized oxides have been concentrated on low temperature properties. Detailed knowledge of the temperature characteristics of the oxide is however necessary both when the oxide is used in a process involving elevated temperatures and when the oxide is an integral part of a device operated at elevated temperatures.

Native GaAs oxide up to 8000 Å thick was made by anodizing GaAs in a mixed solution consisting of aqueous tartaric acid solution and ethylene glycol[(1)]. The method will be presented regarding composition and characteristics of the electrolyte, growth rate and anodization conditions. Basic properties, including optical characteristics, were investigated and will be reported. The remainder of this summary emphasizes the influence of temperature on the oxide structure and composition.

The oxide was heat-treated at different temperatures for different periods of time. The as-grown oxide is stable and homogeneous with a Ga: As ratio of 1: 1. Below 350°C no change of structure and composition of the oxide can be observed. Above 350°C the oxide begins to dissociate first by releasing water. The oxide dissociation occurs very rapidly around 450°C by a combined effect of vaporization of mainly water and arsenic monoxide. The oxide thickness notably decreases and the structure becomes inhomogeneous and arsenic depleted. During dissociation, the oxide structure becomes more and more gallium-oxide rich and the dissociation is completed at 700°C resulting in a pure and homogeneous gallium-oxide structure. The gallium-oxide is expected to be β-Ga_2O_3 judging from the optical properties and the etching characteristics. Above 650°C, sublimation of arsenic from GaAs becomes notable and with it, a new layer grows in GaAs at the oxide-GaAs interface. The interface layer is difficult to identify but is assumed to be amorphous or poly-crystalline material based on arsenic depleted GaAs.

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Decomposition of the oxide and sublimation of decomposed materials are so rapid that at a given temperature almost all change is completed during the early stage of the heat-treatment. A period of 15 minutes is for instance enough at 450°C and the duration becomes shorter at a higher temperature. By Logan et al., the composition of the oxide is a mixed structure of Ga_2O_3, As_2O_3 and H_2O [(2)]. Binding of H_2O is not so strong and is therefore easily released above 350°C. Furthermore As_2O_3 is not stable and it decomposes and vaporizes as AsO above 400°C. On the other hand, Ga_2O_3 is very stable even above 700°C.

From this investigation it is concluded:

1 The as-grown oxide is stable up to 350°C.

2 From a reliability point of view the as-grown oxide can be used up to 350°C.

3 The oxide dissociates above 350°C.

4 If device operation above 350°C is required or if the oxide is used in a high temperature device processing step the oxide must be stabilized. It is however important to note that the required anneal-time is very short. The oxide is for instance stabilized in 15 minutes at 450°C.

5 The oxide changes to pure gallium oxide at 700°C.

6 Successful high temperature ($T \approx 750°C$) processing has been achieved using a two layer structure — a SiO_2 coating layer on top of the anodized oxide — and these results will be presented.

(1) H. Hasegawa, K. E. Forward and H. Hartnagel, "Improved Method of Anodic Oxidation of GaAs", Electron. Lett., 11, 53(1975).

(2) R. A. Logan, B. Schwartz and W. J. Sundburg, "The Anodic Oxidation of GaAs in Aqueous H_2O_2 Solution", J. Electrochem. Soc., 120, 1385(1973).